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GB 2304760 A WO 98/34006 A1 WO 98/13572 A1

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(54) Abstract Title
Method for milling casing and drilling formation using a dual function drill bit

(57) A dual function drag bit 11 is used in a method for both milling well casing 40 or liner and subsequently drilling rock formation 41 without the sequential removal of a milling assembly and replacement with a drilling assembly. The method employs a cutting tool that is capable of both milling steel pipe casing in a well bore and subsequently drilling rock formation outside the well bore after passing through the casing. In one embodiment, inserts (16, figure 3) designed for embedding into the surface of a cutting tool 11 comprise at least an outer layer (22, figure 3), such as cemented tungsten carbide, capable of milling steel, and at least a second layer (23, figure 3), such as polycrystalline diamond , capable of drilling formation, the two layers being bonded together and to a carbide substrate (24, figure 3). In another embodiment, inserts 16 with a polycrystalline diamond cutting face for drilling rock formation are in parallel with cemented tungsten carbide cutters 45 for milling steel casing.

FIG. 1

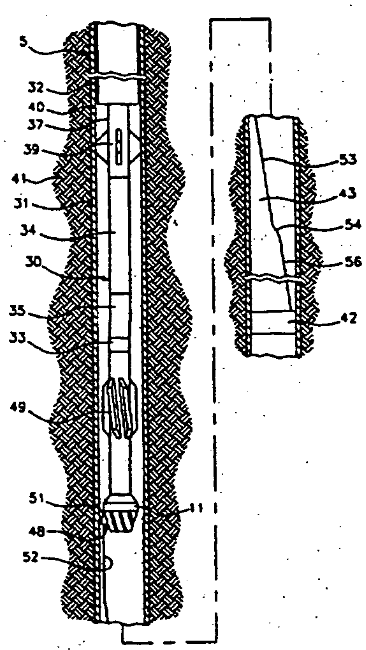

FIG. 2

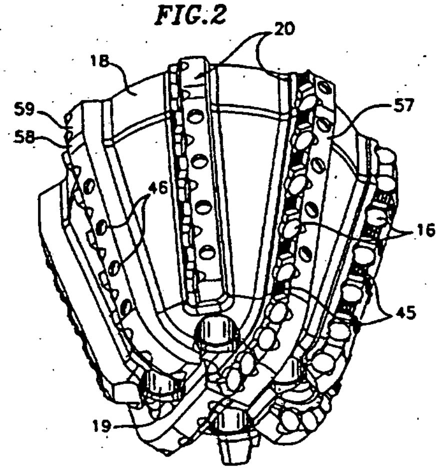

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FIG.2

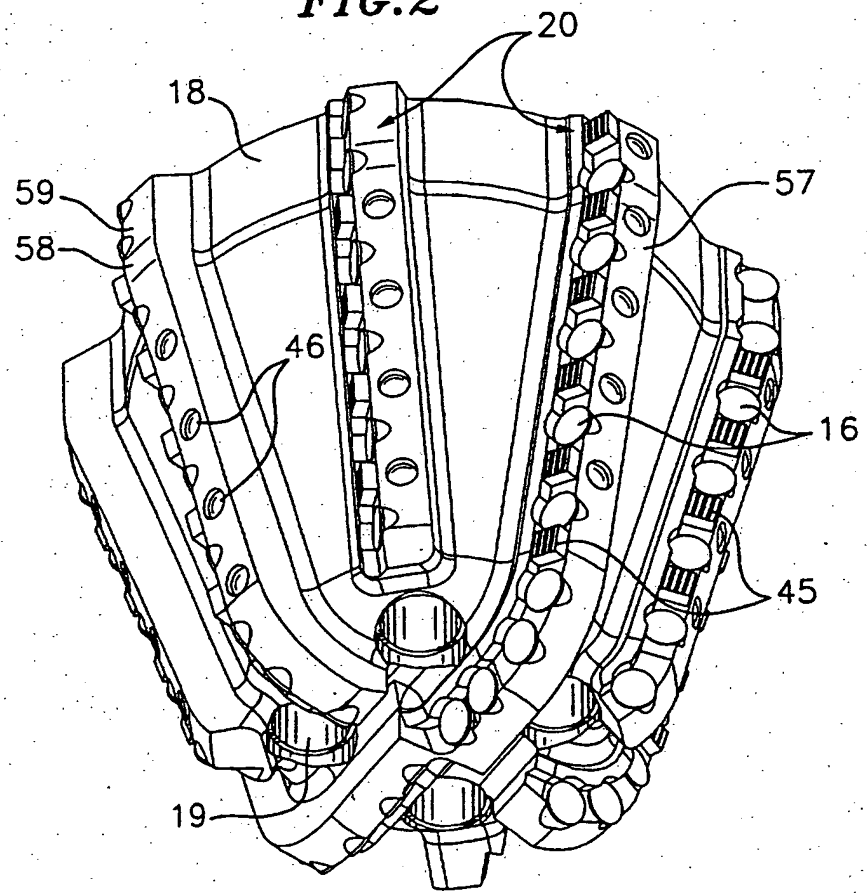


FIG.3

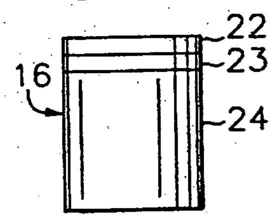


FIG.4

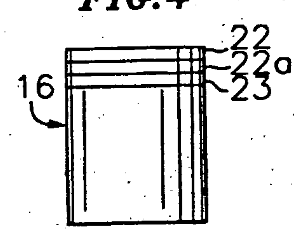


FIG.5

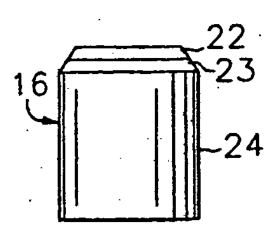


FIG.6

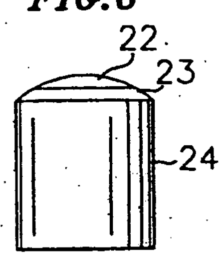
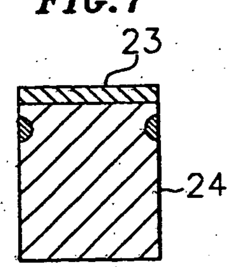


FIG.7



disclosed system requires three trips into the well, beginning with the creation of an initial window in the borehole casing, the extension of the initial window with a particular cutting tool, and the elongation and further extension of the window by employing an assembly with multiple mills.

By integrating a whipstock into the milling operation and directionally orienting the milling operation to a more confined area of well casing, the number of trips required to effectively mill a window in a well casing have been decreased. A whipstock having an acutely angled ramp is first anchored inside a well and properly oriented to direct a drill string in the appropriate direction. A second trip is required to actually begin milling operations. Newer methods integrate the whipstock with the milling assembly to provide a combination whipstock and staged sidetrack mill. The milling assembly is connected at its leading tool to the top portion of the whipstock by a bolt which, upon application of sufficient pressure, may be sheared off to free the milling assembly. The cutting tool employed to mill through the metal casing of the borehole has conventionally incorporated cutters which comprise at least one material layer, such as preformed or crushed tungsten carbide bonded to a carrier, designed to only mill pipe casing. The mills used for milling casing are not suitable for extensive drilling of rock formation.

Once a sufficient window has been created, the milling assembly is removed and the drilling assembly is inserted into the borehole and directed to the newly formed window to drill earthen formation. Directional drilling is achieved by a number of conventional methods, such as steerable systems, which, when used, control borehole deviation without requiring the drilling assembly to be withdrawn during operation.

A typical system may use a bottom hole motor with a bent housing having one fixed diameter bit stabilizer below the housing and one stabilizer above the housing in combination with a measurement-while-drilling (MWD) system. Deviation is achieved by using the motor output shaft to rotate the drill bit while

employ a method and incorporate the requisite devices which would both mill a window in the original well casing and subsequently drill formation through the newly created window in a single step.

It would be desirable to provide a method and device which enables the milling of pipe casing and subsequent drilling of formation without requiring multiple trips.

The present invention employs a dual-function cutting tool that is capable of milling pipe casing and/or liner and subsequently drilling formation. An exemplary cutter embedded in the cutting tool comprises at least a first material layer, such as cemented tungsten carbide, capable of milling pipe casing and/or liner and at least a second material layer, such as polycrystalline diamond, capable of drilling formation, the two layers being bonded together and to an insert body. The thickness and configurations of the material layers relative to each other and to the carrier vary and may include beveled and twin edge constructions which vary the cutting surface and improve the milling and drilling operation.

The cutting tool body is attached to a bottom hole assembly that connects to the drill string. The cutting tool may be optionally attachable to a whipstock to integrate the packing, anchoring, and orienting of a whipstock with the insertion of the milling and drilling assembly, thereby eliminating the need for a separate whipstock placement trip.

The milling and drilling process is conducted by shearing off the connection between the whipstock and cutting tool and directing the dual function milling and drilling assembly down the whipstock incline toward the well casing. After a window is milled through the casing, directional drilling can then proceed by any conventional method. The same cutting tool is used for both milling the casing and drilling the rock formation beyond

some level (referred to as a liner hanger point) below the ground surface. Typically, either casing or liner is cemented in the well bore with a cement grout. Since both are steel pipe and it makes no difference for practice of this invention where the pipe is suspended, the pipe is referred to herein simply as casing.

A preferred embodiment of an apparatus capable of practicing the method of the present invention is shown in FIG. 1. A bottom hole assembly 30 with a cutting tool 11 which has the capability of both milling well pipe casing 40 and drilling earthen formation 41 includes a series of tools 32-39 between the cutting tool 11 and the drill pipe 31, described in greater detail hereinafter.

Unlike conventional cutting tools, the cutting tool 11 employed in the present invention is multi functional in that it is designed to both mill pipe casing 40 and subsequently drill earthen formation 41. While the present invention is not limited to any particular design for a multi functional cutting tool capable of sequentially milling pipe casing and drilling formation, an exemplary embodiment of the cutting tool 11 is provided in FIG. 2.

In the embodiment shown in FIG. 2, the cutting tool 11, of a form commonly referred to as a drag bit, comprises a body 18 with a threaded shank at the top (hidden in this view) for connection to a bottom hole assembly 30. The body 18 may be formed from steel or a tungsten carbide matrix infiltrated with a binder alloy or any other material used in the art. Extending outwardly from the base of the cutting tool body 18 are a series of arched projections or blades 20 which comprise the cutting tool surface and into which are embedded inserts or cutters 16. Within the cutting tool body 18 are one or more passages ending in openings 19 through which drilling fluid may be delivered to cool the cutting tool surface and remove accumulated debris.

In the illustrated embodiment, the inserts 16 comprise 13 mm diameter cylindrical bodies of cemented tungsten carbide with a layer of polycrystalline diamond (PCD) on an end face. Each

As an alternative to providing separate pieces of cemented tungsten carbide on the face of the blades for cutting steel, carbide can be provided on the face of some or all of the PCD inserts. Such a layer of carbide can be used for milling steel casing, and after the bit enters rock formation, the carbide is eroded away leaving the PCD layer exposed for drilling rock formation.

As shown in FIG. 3, such an insert 16 comprises material layers 22, 23 which are bonded onto a carrier substrate 24 and then secured into the cutting surface of the cutting tool. As stated previously, the material layers have conventionally been designed to be mono-functional. The present invention uses a first material layer 22 which is capable of milling pipe casing, such as 9 5/8 inch steel casing, bonded to a second material layer 23 which is capable of drilling earthen formation. The type of metal used in the pipe casing and the type of geological formation being drilled determine the materials to constitute the first or outer layer 22 and second material layer 23.

Materials such as polycrystalline diamond, polycrystalline cubic boron nitride (PCBN), natural diamond, titanium nitride, tungsten carbide or tungsten carbide cemented with cobalt can be used in either the first layer 22 or second material layer 23, as suitable for the intended functions of milling steel casing or drilling rock formation, respectively. It is within the knowledge of one skilled in the art to choose the proper combination of material layers based upon the type of casing and geological formations being encountered.

If milling a 9-5/8 inch steel casing, a preferred embodiment of the present invention employs a first material layer 22 made of cemented tungsten carbide bonded to a second material layer 23 made of polycrystalline diamond. PCBN can be used in the first material layer 22 but, relative to a milling grade of tungsten carbide, it does not mill steel as effectively. Both tungsten carbide and PCBN are preferred materials for the first

and is dependent and determined by the expected wear profile. One preferred embodiment, shown in FIG. 5, employs a beveled structure where the first layer 22 substantially covers the second layer 23 and both material layers 22, 23 cover the face of the insert body. The beveled edge has an angle corresponding to the rake angle of the insert mounted in the bit body. This may improve the performance of the insert and minimize chipping. For directional drilling, a rounded insert profile, shown in FIG. 6 can be used to attain sufficient side loading. Different geometries of insert may be used in the gage rows and in inner rows on the cutting tool.

The cutting tool 11 is used in conjunction with a bottom hole assembly 30 which stabilizes the cutting tool, provides the motive force for rotating the cutting tool, and after milling through casing, directionally controls the movement of the cutting tool in rock formation. While components of the bottom hole assembly may be varied without exceeding the scope of the claimed invention, the bottom hole assembly is described in relation to an exemplary embodiment illustrated semi-schematically in FIG. 1. It will be recognized that the relative lengths and diameters of the parts of the bottom hole assembly may be rather different from what is illustrated.

The bottom hole assembly 30 comprises drill collars 32, a rotatable shaft 33, a bottom-hole motor output shaft (not shown), bottom-hole motor 34, a bent housing 35, one or more stabilizers 39 and a connector sub 37. The cutting assembly includes cutting tool 11 for milling casing and drilling rock formation as provided in practice of this invention, and a second milling tool 49 above the cutting tool. The cutting tool 11 opens a window through the casing in a well and the second milling tool enlarges and cleans up the shape of the window. A third milling tool may also be used if desired. The second and third milling tools are conventional watermelon mills or window mills.

The cutting assembly connects to the bottom hole assembly 30 by connecting to the rotatable shaft 33 which, in turn, is

The bottom hole assembly can be connected to the whipstock to both facilitate positioning and eliminate the requirement of separate trips for positioning the whipstock and initiating milling and drilling operations. The cutting tool 11 may be connected to the top portion of the whipstock by a bolt 48 which, upon application of sufficient pressure, is sheared off, thereby releasing the bottom hole assembly from its fixed position relative to the whipstock and permitting it to proceed down a path toward the pipe casing defined by the inclination of the face of the whipstock. The connection between the bit and the whipstock may be hollow and/or connected via a port through the body of the bit so that upon shearing off of the connection, the port is opened and serves as a fluid port during the milling and drilling operation.

The drag bit for milling casing and drilling adjacent rock formation after a window is cut through the casing, is preferably used with a whipstock having complementary surfaces, as described in U.S. Patent Application Serial No. 08/642,829, assigned to the same assignee as this application. The subject matter of the pending application is hereby incorporated by reference.

In a typical embodiment, the whipstock has a ramp surface with several different angles relative to the axis of the borehole in which it is placed. At the upper end of the whipstock there is a short surface 51 having an angle of about 15° which is useful for starting the cutting of a window. Just below the starting ramp 51, there is an elongated surface 52, which is parallel to the axis of the hole. The length of the parallel surface is about the same as the distance between the first cutting tool 11 and the second milling tool 49. Next, going down the borehole, there is a ramp surface 52 on the whipstock with an angle of about 3° from the borehole axis. The 3° surface continues until it reaches approximately the centerline of the borehole. At that elevation there is a short 15° "kickoff" surface 54. Below the kickoff surface the face of the whipstock reverts to a 3° angle.

3° portion of the cutting tool engages the 3° ramp surface 53 on the whipstock, and is further forced laterally into the casing and surrounding cement; gradually enlarging both the length and width of the window through the casing. The watermelon mill follows, cleaning up the window made by the cutting tool.

As the center of the cutting tool approaches a point where it should be milling casing, the 15° portion of the cutting tool engages the kickoff surface 54. This tends to force the cutting tool laterally through the casing and surrounding cement at a relatively rapid rate through the portion of the milling operation where the center of the cutting tool is cutting the steel of the casing. This is a part of the milling operation where the rate of penetration is relatively lower and is desired to proceed through this part rapidly.

After the center of the dual function cutting tool has passed through the casing, the cutting tool engages the final 3° ramp 56 on the whipstock and proceeds to enlarge the window through the casing and extend further into the rock formation. Meanwhile, the second milling tool 49 continues to enlarge and clean up the window through the casing.

Typically, in the past, the sidetracking operation has continued after the initial milling tool has passed through the casing to produce a short rat hole in the formation adjacent to the original borehole, which has sufficient length to accommodate at least the second (and third if used) milling tools, and usually a small additional portion of the bottom hole assembly. The prudent driller typically makes the rat hole deep enough to assure that the subsequent drill bit will pass cleanly through the window. A typical rat hole is four or five meters deep and is not drilled deep enough to accept the entire bottom hole assembly.

The bottom hole assembly embodiment of FIG. 1 permits the exertion of directional control over the milling and drilling process. As discussed in RE 33,751, the offset of the cutting tool from center, created by the bend angle of the bent housing

Further cutting of the rock formation outside the casing is usually undesirable since the conventional casing mill is designed specifically for cutting casing and is not particularly well suited for drilling formation. Certainly the milling tool would not be run into the formation more than fifteen meters beyond the bottom of the window, far beyond the usual depth of the rat hole. The casing mill wears rapidly in the rock formation and is not suitable for drilling to the next liner hanger point or true bottom of the well. At the point where a rat hole has been formed, a conventional casing mill would be withdrawn from the borehole and a conventional drill bit run in for drilling rock formation outside the casing. The conventional drill bit is not particularly well suited for milling casing and would, typically, have unacceptable wear when so used.

In practice of this invention, however, the same drag bit is used for milling through the casing and for drilling rock formation to the next liner hanger point, for example. This is typically more than fifteen meters beyond the sidetracked well bore, much further than a traditional rat hole. As the dual-function bit drills further into the formation the downhole motor and bent housing assembly are used for steering to provide directional control of the borehole being drilled. Alternatively, steering may be provided by way of a steerable bottom hole assembly on a rotating drill string.

In an embodiment with inserts as described and illustrated in Fig. 3 are employed, when the inserts 16 have had the outer material layer designed to mill the pipe casing worn away, the second material layer 23 designed to drill formation is exposed. The drilling of rock formation continues due to the rotary application of the combined milling and drilling tool to formation for a desired distance beyond the length of a conventional rat hole. The drilling of formation can continue without requiring the removal and/or replacement of the drilling assembly until the next liner hanger point is reached by the

wear away in the rock formation and the PCD inserts take over the drilling operation.

In an exemplary sidetracking operation, a window may be cut in a 9-5/8 inch casing and about 100 meters of hole drilled with an 8-1/2 inch drilling bit. A 7-1/2 inch liner is then cemented in the sidetracked hole, and a 4-1/2 inch bit used to drill further into the formation. Traditionally, two bits are used for milling the casing and drilling the 100 meter extension. With this invention, a single dual function drag type bit with PCD inserts may be used for both milling a window through the casing and extending the hole 100 meters or more through the formation for placement of a liner.

In another embodiment, a layer of PCD may be formed on a carbide body. This is covered with a layer of titanium nitride or titanium carbonitride which is used as the material for milling the steel casing.

Still another embodiment of insert, as illustrated in FIG. 7, has what amounts to two cutting edges. A carbide body 24 has a layer 23 of PCD on an end face. A layer of carbide may be formed or brazed over the PCD if desired, or the diamond layer may be used for milling the steel casing. In this embodiment there is also a ring or band of PCD formed in a circumferential groove around the cemented tungsten carbide body. As this embodiment of insert is used, the layer of PCD on the front face may wear and the additional band of PCD then serves as a second cutting edge. If desired, the edges of the insert may be beveled at the rake angle so that the second cutting edge is exposed at the beginning of drilling.

The inserts described and illustrated herein have each featured a cylindrical cemented tungsten carbide body with layers of material for milling casing and drilling rock formation on one end face. It will be apparent to those familiar with drag bits that other types of inserts may be employed. For example, one popular type of PCD insert has a disk-like carbide substrate with a layer of PCD formed on one face. This disk of carbide is

CLAIMS

1. A method of drilling a portion of a well comprising the steps of:

introducing a dual function tool into a well bore;

milling a window in well casing in the well bore with the dual function tool, including drilling a rat hole in formation adjacent to the well bore; and

continuing to drill formation beyond the end of the rat hole with the same dual function tool.

2. A method of drilling a portion of a well comprising the steps of:

introducing a dual function tool into a well bore;

milling a window in well casing in the well bore with the dual function tool; and

continuing to drill formation adjacent to the well bore with the same dual function tool until at least an entire bottom hole assembly connected to the dual function tool has passed through the window in the well casing.

3. A method of drilling a portion of a well comprising the steps of:

placing a sidetracking whipstock in a well bore;

introducing a dual function tool into the well bore;

milling a window in well casing adjacent to the whipstock with the dual function tool; and

continuing to drill formation adjacent to the well bore with the same dual function tool beyond a location where the whipstock has an influence on the direction of drilling by the dual function tool.

continuing to drill formation adjacent to the well bore with the same dual function tool to the true end of the well.

8. A dual function bit for milling casing in a well bore and for drilling rock formation outside the well bore comprising:

a drag bit body; and

a plurality of inserts in the drag bit body, each of the inserts comprising:

an insert body,

a layer of polycrystalline diamond material on a cutting face of the insert body, and

a layer of softer material over the layer of polycrystalline diamond, the softer material layer having a sufficient hardness and thickness for milling through steel casing in a well bore.

9. A dual function bit according to claim 8 wherein the layer of softer material is selected from the group consisting of polycrystalline cubic boron nitride, titanium nitride, titanium carbonitride, tungsten carbide or cemented tungsten carbide.

10. A dual function bit according to claim 8 wherein the layer of softer material comprises cemented tungsten carbide.

11. A dual function bit for milling casing in a well bore and for drilling rock formation outside the well bore comprising:

a drag bit body; and

a plurality of inserts in the drag bit body, each of the inserts comprising an insert body having a layer of polycrystalline diamond material on a cutting face of the insert body for drilling rock formation; and

a plurality of cemented tungsten carbide cutters mounted on the body in parallel with the inserts for milling steel casing.

The Patent Office

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Application No: GB 9903332.6
Claims searched: 1

Examiner: Dr. Robert Fender
Date of search: 10 May 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): E1F

Int Cl (Ed.6): E21B

Other: Online: WPI, EPODOC

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2304760 A	(TIW CORPORATION)	1
X, E	WO 98/13572 A1	(BAKER HUGHES INCORPORATED)	1
A	WO 98/34006 A1	(WEATHERFORD/LAMB)	-

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